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DESIGNING INTERVENTIONS THAT INCLUDE DELAYED REINFORCEMENT: IMPLICATIONS OF RECENT LABORATORY RESEARCH

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The search for robust and durable interventions in everyday situations typically involves the use of delayed reinforcers, sometimes delivered well after a target behavior occurs. Integrating the findings from laboratory research on delayed reinforcement can contribute to the design and analysis of those applied interventions. As illustrations, we examine articles from the *Journal of the Experimental Analysis of Behavior* that analyzed delayed reinforcement with respect to response allocation (A. M. Williams & Lattal, 1999), stimulus chaining (B. A. Williams, 1999), and self-control (Jackson & Hackenberg, 1996). These studies help to clarify the conditions under which delayed reinforcement (a) exercises control of behavior, (b) entails conditioned reinforcement, and (c) displaces the effects of immediate reinforcement. The research has applied implications, including the development of positive social behavior and teaching people to make adaptive choices.

DESCRIPTORS: delayed reinforcement, response allocation, stimulus chains, self-control, integration of basic and applied research

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Establishing the initial instances of a behavioral repertoire typically requires the use of programmed consequences that occur immediately after the target response occurs. However, the job of the applied behavior analyst also involves the strategic use of delayed reinforcement. Behaviors that yield delayed reinforcement are highly adaptive in everyday life, but they may be difficult to establish and maintain. Such difficulties raise empirical questions about how delayed reinforcement exercises control and how intervening stimulus events might enhance its effects on behavior. The use of delayed reinforcement also may be challenging when there are favorable contingencies for behaviors that are incompatible with those that satisfy the delayed consequences, even when the reinforcers involved are relatively small or less preferred. As discussed later, exercising self-control is a matter of learning to forgo engaging in behaviors that yield immediate reinforcers in favor of behaviors that yield delayed reinforcers.

Because of its practical significance, and because of the difficulties involved in its systematic arrangement, applied researchers

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could benefit from the knowledge gained in numerous laboratory studies on the topic of delayed reinforcement to better integrate basic and applied sciences. In a previous article in this series, Hayes and Hayes (1993) emphasized that the effects of events that happen during a delay, such as delivery of tokens or teaching someone to self-instruct, are important for a behavioral analysis. The present article extends that discussion by examining three other empirical papers recently published in the *Journal of the Experimental Analysis of Behavior* (*JEAB*) concerned with delayed reinforcement. The studies examined response–reinforcer relations with respect to delayed, unsignaled reinforcement (A. M. Williams & Lattal, 1999), stimulus chaining (B. A. Williams, 1999), and self-control (Jackson & Hackenberg, 1996). To easily connect basic concepts to areas of application, we begin by describing scenarios derived from research published in the *Journal of Applied Behavior Analysis* that involved delayed reinforcement. We then describe some of the methods and results of the *JEAB* target articles, and suggest ways of integrating that information with applied behavior analysis by referring to the case scenarios.

Delayed Reinforcement in Applied Settings

The following case scenarios illustrate practical situations in which the interventions involve delayed reinforcement. We consider the applied goals of (a) promoting sharing and cooperation, (b) completing assigned activities, and (c) substituting functional requests for aggression.

Promoting sharing and cooperation. With a basic social repertoire intact, delivering reinforcement later rather than sooner may actually increase positive social behavior. Consider a preschooler with typical development who seldom shares or cooperates with other children during free play (Fowler & Baer, 1981). To increase socialization, the child is taken aside before a day's play periods to briefly rehearse the social skills desired. The child is also told to exhibit those skills during that day's free play. Then, the child is observed during two play periods, one held early in the day and one held later. After a play period, if positive social behavior occurs, the child receives a sticker that is exchanged for a toy. When such reinforcement occurs after the early play period, sharing and cooperation increase during that period but not during the late play period. However, if reinforcement is delivered at the end of the preschool day, positive social behavior increases during *both* the early and late play periods. This happens even though there are no exteroceptive cues or signals (such as verbal reminders, tokens, etc.) that the delayed reinforcers will be provided. As discussed below, this scenario has a lot in common with A. M. Williams and Lattal's (1999) study of delayed reinforcement with pigeons.

Completing assigned activities. An explicit learning history may be needed to establish the self-control choices that yield large delayed reinforcers rather than impulsive choices that yield small immediate reinforcers (e.g., Ainslie, 1974; Mazur, 1998; Rachlin & Green, 1972). Suppose self-control methods are to be used with an adult with mental retardation (Dixon et al., 1998). Part of the adult's day-treatment program entails sitting with a small group engaging in learning activities. The adult has difficulty doing this and is often prompted to remain seated and complete a task. Verbal instructions are tried first, and the adult is promised a large reinforcer (three crossword puzzles) for finishing the day's activity. Neither of these approaches improves performance, but the following intervention does: During an initial assessment, the adult consistently chooses a large reinforcer (three crossword puzzles) instead of a small reinforcer (one crossword puzzle). Then, the adult is offered the small reinforcer immediately (in effect, for doing no work) or the large reinforcer for doing just a little (5 min) of a day's activity. As a result, the adult opts for doing the activity for 5 min and receives the large reinforcer. Gradually, the amount of time required is increased until the objective is met: 25 min of sustained participation in the day's scheduled activities. Thus the use of signals (instructions) encourages behaviors that yield large delayed reinforcers and helps to increase tolerance for delays.

Substituting requests for aggression. Aggression in some individuals might be conceptualized as impulsive behavior (Vollmer, Borrero, Lalli, & Daniel, 1999). During a clinical assessment, when a participant with developmental disabilities is aggressive (e.g., hitting, kicking, and scratching), a small reinforcer (e.g., one potato chip or 30 s of watching television) is delivered; but when the participant mands appropriately by handing the teacher a picture card, a large reinforcer (e.g., three potato chips or 60 s of watching television) is delivered. Under these conditions, the participant shows a preference for manding over aggression. However, aggression increases when the small reinforcer is delivered immediately following it and manding produces a delay to the large delayed reinforcer. Such impulsive choices are altered by delivering the large reinforcer at the end of a signaled delay (e.g., a reinforcer is visible during the delay; the delay is marked with a kitchen timer). Thus, the participant exhibits self-control when the longer delay is signaled, and exhibits impulsive choices when the longer delay is unsignaled. Studies by B. A. Williams (1999) and Jackson and Hackenberg (1996) described below are germane to these two scenarios.

Basic Research Related to Delayed Reinforcement

The role of signals. Delayed reinforcement can be arranged to establish and maintain responding in the absence of shaping or other training (e.g., Lattal & Williams, 1997). This phenomenon has been demonstrated across several species, including rats and pigeons (Lattal & Gleeson, 1990; Wilkenfield, Nickel, Blakely, & Poling, 1992), Siamese fighting fish (Lattal & Metzger, 1994), and human infants (Reeve, Reeve, Brown, Brown, & Poulson, 1992). The findings of such studies consistently demonstrate that unsignaled delayed reinforcement produces low but persistent rates of responding (Critchfield & Lattal, 1993; Lattal & Gleeson, 1990; Wilkenfield et al., 1992). A recent study by A. M. Williams and Lattal (1999) with pigeons contributes to the basic literature on delayed reinforcement and provides some potential avenues of research for the application of delayed reinforcement.

A. M. Williams and Lattal (1999) arranged a concurrent schedule in which a pigeon's pecks on one key did not produce any consequences (the irrelevant key) and pecks on the other key were reinforced on a tandem schedule involving variable-interval (VI) 15-s and differential-reinforcement-of-other-behavior (DRO) 10-s components (the relevant key). Thus, responding on the relevant key initiated the DRO 10-s schedule an average of once every 15 s, and responding on either key during the DRO interval reset the delay interval. Selection of the left or right key as the relevant operandum occurred before each session, based on a semirandom sequence that limited assignment of the same key as the relevant operandum to no more than three consecutive sessions. The resultant data demonstrated that, overall, the pigeons allocated more responses to the relevant than to the irrelevant key. Analysis of the data indicated that (a) unsignaled resetting delays can maintain a higher relative rate of responding, (b) control by a particular response–reinforcer relation increases with longer histories of exposure to that relation, and (c) the response–reinforcer relation and not some other behavioral process is primarily responsible for the sustained low response rates that occur with unsignaled resetting delayed reinforcement.

Application: The role of signals and response allocation. Aberrant and adaptive behaviors may be viewed as concurrent schedules (e.g., Fisher & Mazur, 1997; Mace & Roberts, 1993; McComas & Mace, in press) that are influenced by four variables: rate, quality, and immediacy of reinforcement, as well as response effort (McDowell, 1988). To the extent that the parameters of these variables are understood, they can be arranged to optimize the effects of reinforcement for an individual in a given situation. Applications of these reinforcement and response parameters have demonstrated the effects of concurrent reinforcement contingencies on response allocation across aberrant and appropriate response alternatives (Horner & Day, 1991; Peck et al., 1996). Specifically, concurrent schedules are often arranged in which a functionally equivalent appropriate alternative response (often a mand for the identified reinforcer) produces a more favorable schedule of reinforcement relative to the aberrant behavior. Few applied studies have demonstrated the effects of delayed reinforcement in this type of concurrent-schedules arrangement (Vollmer et al., 1999). Questions remain regarding how delayed reinforcement can be arranged within concurrent schedules to generate an appropriate alternative response that will effectively compete with the aberrant behavior and maintain the appropriate alternative response at a higher rate relative to the occurrence of aberrant behavior.

Whereas delayed reinforcement can effectively establish and maintain responding, it can also reduce the occurrence of steady-state responding. B. A. Williams (1976) examined the effects of an unsignaled delayed reinforcement procedure that involved a VI schedule in which completion of the response requirement began a delay timer, with the reinforcer being delivered at the end of the interval. Delays as short as 3 s substantially reduced the pigeons' responding from its steady state. Moreover, responses could occur during the delay, such that obtained delays were often shorter than scheduled delays. These findings suggest that in order to avoid the occurrence of behavior during the delay (e.g., the development of a response chain consisting of the appropriate behavior followed by the aberrant behavior, as reported by Wacker et al. (1990), it may be important to incorporate a DRO requirement during the delay (A. M. Williams & Lattal, 1999).

Signals may be an important variable to consider when the goal involves maintenance of appropriate alternative behavior on delayed reinforcement schedules within concurrent schedules. For example, Lattal (1984) found that signaled delays maintained a higher rate of responding in pigeons than did unsignaled delays. Similarly, Vollmer et al. (1999) demonstrated that appropriate alternative responding could be maintained by signaled delays of up to 10 min, whereas unsignaled delays failed to maintain the same behavior for more than 60 s (see discussion below). In addition, aggression occurred at much lower rates when delays were signaled than when they were not. Whether a DRO component would be a viable alternative or supplement to Vollmer et al.'s treatment package is a possibility worth further research.

The particular arrangement of the delay interval is another factor that appears to influence response allocation in concurrent schedules involving delayed reinforcement. Specifically, basic research on concurrent schedules has demonstrated that pigeons show greater response allocation to keys associated with mixed delays than to those associated with a constant delay (Chelonis, King, Logue, & Tobin, 1994; Cicerone, 1976). Furthermore, intermittent or partial delays appear to increase resistance to extinction, whereas constant delays appear to weaken resistance (Crum, Brown, & Bitterman, 1951; Nevin, 1974; Tombaugh, 1966). Thus, there are numerous factors to consider in the arrangement of delayed reinforcement for establishing and maintaining an appropriate alternative response in the context of aberrant behavior.

Stimulus chains. Simultaneous discrimination learning is known to be impaired when the consequences of a correct choice are delayed relative to when those consequences are immediate. The presentation of stimulus events during the delay may reverse these effects on discrimination learning. B. A. Williams (1999) examined the processes responsible for the facilitation of discrimination learning by stimuli inserted within a delay-to-reinforcement interval. He considered three hypotheses: First, choice for delayed reinforcement would be more likely when stimuli presented during the delay reliably predicted reinforcement and thus functioned as conditioned reinforcers. Second, stimuli presented during a delay interval serve to bridge the response and the delayed outcome, such that choice for the delayed reinforcer would be more likely when the choice response and the intervening stimuli were highly correlated. Third, intervening stimuli mark the choice response and cause it to become more memorable at the time of the delayed reinforcer delivery, such that changes in the correlation between intervening stimuli and a delayed reinforcer would affect discrimination learning only minimally. B. A. Williams' study differed from previous ones that examined the effects of delayed reinforcement on discrimination learning, in which only a single stimulus is typically presented during the delay-to-reinforcement interval. This stands in contrast to studies of chain schedules of reinforcement, which have shown that the greater the number of intervening stimuli, the more poorly choice behavior is maintained (e.g., Duncan & Fantino, 1972).

In B. A. Williams' (1999) procedure, 8 rats were trained to simultaneously discriminate between two levers. Responding to one lever reliably produced reinforcement on a VI 20-s reinforcement schedule, and choosing the other lever produced no reinforcement. Two-link stimulus chains were programmed to occur for specified durations during the delay intervals following each choice response. The middle- and terminal-link stimuli of each chain terminated automatically according to a variable-time 15-s schedule or a fixed-time 20-s schedule. Once this initial discrimination was established, the outcomes for the two levers were altered in a series of contingency reversals. The correlations of the stimuli of each chain with delayed reinforcement or no reinforcement were also varied across reversals, such that either the middle-link or terminal-link stimulus of each chain could have the same or opposite correlation with reinforcement as it had during the preceding reversal. A total of four types of reversals were presented. Each subject received one reversal for each of the four possible types. If a conditioned reinforcement hypothesis accounted for facilitated discriminations, consistent stimulus–reinforcer correlations across successive reversals were expected to facilitate learning. If bridging explained improvement in discrimination, it was expected that changing the correlations between the choice response and the intervening stimuli would disrupt learning. If enhanced learning was due to the marking of the correct choice response by the onset of the intervening stimuli, changes in the correlations between the intervening stimuli and trial outcome would be irrelevant.

B. A. Williams' (1999) results demonstrated that new discriminations were acquired more rapidly when the correlations between the stimuli and consequences were the same as they had been during each preceding contingency reversal. Moreover, the main determinant of acquisition rate was whether or not the middle-link stimulus was correlated with the same outcome as it had been during the preceding reversal. When the status of the middle-link stimulus as a predictor of reinforcement did not change relative to preceding reversals, changes in the status of the terminal-link stimulus affected the rate of discrimination only minimally. Alternatively, when the status of the middle-link stimulus as a predictor of reinforcement did change relative to preceding reversals, the status of the terminal-link stimulus as a predictor of reinforcement became much more important. B. A. Williams contended that the stimuli presented during the delay gained their conditioned value through a backward chaining effect. These results are thus consistent with a conditioned reinforcement explanation for the facilitative role of stimuli presented during a delay-to-reinforcement interval and coincide with those reported elsewhere (e.g., Alsop, Stewart, & Honig, 1994; Dunn, Williams, & Royalty, 1987; B. A. Williams & Dunn, 1991).

Application: Stimulus and response chains. These results are important, because they suggest that learning to discriminate between situations resulting in delayed reinforcement or no reinforcement may be enhanced if stimuli that reliably predict reinforcement are presented during the delay. Moreover, the correlation between those stimuli and reinforcement must not be altered. For example, a child might be given the choice of doing a specified amount of work in class and earning the privilege to engage in a desired activity at the end of the day, or doing something other than working and not earning that privilege. In the absence of relevant stimuli indicating when or where the reinforcer will become available, it may be difficult to discriminate between the two options (see Baer, Williams, Osnes, & Stokes, 1984; Fowler & Baer, 1981). The delivery of conditioned reinforcers during the delay before which the activity is available could potentially increase the likelihood that the child will choose to do his or her work. The stimuli will serve as most effective conditioned reinforcers if they are regularly presented contingent upon the target response and if they reliably predict reinforcement. Considerable research has identified the effectiveness of tokens, points, gold stars, and the like in achieving this purpose (Kazdin, 1982; Kazdin & Bootzin, 1972), yet the identification of less contrived, more naturally occurring conditioned reinforcers will be useful for ensuring generalization to other settings. Pictures of a desired object, edible item, or activity may serve a similarly useful purpose when presented during a delay, particularly if the pictures are being used concomitantly in a communication teaching program (e.g., Bondy & Frost, 1993). Conditioned reinforcers might also be verbal in nature (Hayes & Hayes, 1993). Praise from a parent, teacher, or caregiver, or reminders of the reinforcement that is to come, may strengthen the effectiveness of delayed reinforcement when presented during the delay.

Useful procedures might be established by requiring individuals to produce conditioned reinforcers during the delay. Verbal stimuli, for example, might be produced by the individual in the form of spoken or written self-instructions or self-prompts (e.g., see Jay, Grote, & Baer, 1999; Stromer, Mackay, Howell, McVay, & Flusser, 1996; Stromer, Mackay, McVay, & Fowler, 1998; Taylor & O'Reilly, 1997). Functional communication training (Carr & Durand, 1985; Durand & Carr, 1991) might serve as a means by which individuals can produce their own conditioned reinforcers as well. Teaching an individual to mand desired items using chosen pictures may allow the pictures to acquire conditioned reinforcing properties when the specified reinforcer is made available at the end of the delay (Bondy & Frost, 1993).

Sequences or chains of two stimuli were presented during the delays in the B. A. Williams (1999) study. In the most effective arrangement, a middle-link stimulus was presented contingent upon the correct choice response; this was followed by the terminal-link stimulus that signaled the availability of reinforcement at the end of the delay. The programming of chains of conditioned reinforcers in practical settings may be useful in facilitating the effectiveness of delayed reinforcement, particularly when the delays are relatively long. As an example of such a chain, consider a teaching situation in which a child (a) accumulates pennies for each correct response, (b) exchanges the pennies for tokens after a specified number of pennies are accumulated, then (c) exchanges the tokens for a desired activity after a specified number of tokens are accumulated. As previously noted, the use of tokens as conditioned reinforcers in applied settings has been elaborated upon a great deal (e.g., Kazdin, 1982; Kazdin & Bootzin, 1972), but how the availability of chains of conditioned reinforcers systematically affects choice making in practical situations is currently unknown. In addition, the identification of more naturally occurring stimulus chains will again be profitable. Finally, basic research has suggested that the greater the number of stimuli presented during a delay, the less likely an individual is to choose the delayed reinforcer (Duncan & Fantino, 1972). What limits there might be on the number of stimuli presented during delays and the facilitative effects reported by B. A. Williams merit examination.

The completion of the activities specified by picture activity schedules or written lists may be regarded as signaled response chains. Reinforcement is not available until the entire sequence of activities is completed, and the completion of one activity is conditionally reinforced by the opportunity to engage in the next activity (MacDuff, Krantz, & McClannahan, 1993; McClannahan & Krantz, 1999). The opportunity to complete response chains might increase the likelihood with which individuals choose response alternatives that lead to delayed reinforcement. In effect, choosing to work could become more probable than choosing not to work, due to the conditioned reinforcing properties of work itself (Eisenberger & Masterson, 1983; Eisenberger & Shank, 1985). The stimuli correlated with each link of a chain (pictures or textual prompts) might also acquire conditioned reinforcing properties that maintain responding during the delay. Again, the limit to the length of such chains ought to be investigated. Response alternatives that lead to no reinforcement may actually be preferable to response alternatives that lead to delayed reinforcement but have very lengthy chain requirements during the delay.

Teaching individuals to make adaptive choices could involve expanding a self-control repertoire via behavioral chaining and delayed reinforcement. The optimism that rather long behavioral chains are achievable comes from the promising applied research on teaching students to follow photographic schedules of school and home activities (Krantz, MacDuff, & McClannahan, 1993; MacDuff et al., 1993). For example, MacDuff et al. taught children with autism to engage in sequences of play activities depicted in a series of photographs. As a result, the children learned to engage in "lengthy response chains," as well as to "independently change activities, and change activities in different group home settings in the absence of immediate supervision and prompts from others" (p. 89). In another example, Lalli, Casey, Goh, and Merlino (1994) used activity-scheduling procedures with older students who exhibited aggression. These investigators also incorporated reading instruction based on laboratory studies of stimulus class formation. By doing so, they demonstrated how students may learn to follow schedules in which the names of the activities are written rather than represented in photographs.

Specifying the methods for establishing an initial repertoire of schedule following will require research. A reasonable place to start would be to use activities that already function as reinforcers (e.g., putting a puzzle together) and have a clearly defined beginning and ending (McClannahan & Krantz, 1999). Such activities could facilitate schedule following. However, performing other activities (e.g., putting things away) may depend on the delivery of highly desirable supplemental reinforcers (e.g., a favorite snack or free play) upon completion of the scheduled activities. For some students, it will also be necessary to ensure that the photographs are functionally related to the activities they depict. For instance, communication training that uses pictures or photographs (e.g., Bondy & Frost, 1993) would be a natural context for establishing the relations among photos and activities that could subsequently enhance learning to follow an activity schedule.

Due to practical constraints, the delivery of delayed reinforcers may at times be uncertain. A teacher may wish to provide students with the opportunity to engage in a desired activity following their completion of homework problems, but may be unable to provide this reinforcer due to instances of aggression on the part of other students or the unavailability of the specified activity. Thus, delayed reinforcers may, under some circumstances, be available with less than a 100% probability. Indeed, unreliable reinforcement may be more typical in instructional and clinical situations than reliable reinforcement. Research has shown that nonhuman subjects are likely to prefer unreliable reinforcement to reliable reinforcement when conditioned reinforcers are presented during delay intervals preceding the availability of the unreliable reinforcement (Belke & Spetch, 1994; Dunn & Spetch, 1990). Little applied research has been conducted in this area, however. Empirical support for the programming of conditioned reinforcers that predict unreliable or uncertain outcomes is necessary (see Lalli & Mauro, 1995).

Self-control. Jackson and Hackenberg (1996) adapted laboratory methods typically used with adult humans without intellectual impairments (e.g., Flora & Pavlik, 1992; Hyten, Madden, & Field, 1994) to examine self-control choices in pigeons. Sorting out the procedural differences that may account for the differences among people and pigeons may help to pinpoint the behavioral process involved (see also Grosch & Neuringer, 1981). Attempts to clarify such issues are timely because of relevance to the broader applied interests in choice (e.g., Fisher & Mazur, 1997) and the ongoing concerns with extending and applying self-control methods to clinical populations (e.g., Dixon et al., 1998; Neef, Mace, & Shade, 1993; Neef, Shade, & Miller, 1994; Vollmer et al., 1999).

The tokens that Jackson and Hackenberg (1996) used with pigeons were light-emitting diodes (LEDs), each exchanged for 2-s access to food. A panel of 34 LEDs accommodated the maximum number of tokens that could be accumulated in a session. There were also green and blue choice response keys and a red token-exchange key. Each session was 12 trials: 2 forced-choice trials followed by 10 free-choice trials. The forced-choice trials ensured that the birds made contact with the contingencies arranged during the session. Conditions central to the study included (a) the immediate delivery of a small token reinforcer (one LED) after pecking one choice key, (b) the delayed (e.g., 6 s) delivery of a large token reinforcer (three LEDs) after pecking the other choice key, and (c) a discrete token-exchange period during which each peck to the exchange key turned off an LED and resulted in 2-s access to food. Gradually, all of the LEDs were exchanged at the end of each 12-trial session; thus, the delay to token exchange was the same for both small and large choices (e.g., Condition ED10, Experiment 2). In other words, the terminal food reinforcer was neither more immediate nor more plentiful for choosing the small token. Including the two forced-choice trials, if a pigeon always pecked "small" (one LED), a total of 14 LEDs would be exchanged for 28 s of food at the end of the session. In contrast, if a pigeon always pecked "large" (three LEDs), 34 LEDs would be exchanged for 68 s of food.

In Experiments 1 and 2, the pigeons' choices proved to be quite sensitive to the timing of the token-exchange periods. That is, access to food was the important variable, irrespective of the LED delays: If the exchange for a large amount of food occurred later than the small amount, the pigeons were more apt to choose the side key related to one LED and the small amount of food. However, if the timing of the exchange for the small and large amounts of food was equal, the birds were more apt to choose the key related to three LEDs and the large amount of food. This finding replicates numerous prior studies with pigeons that involved unequal delays before delivering food reinforcers (e.g., see review by Mazur, 1998), with adult humans exposed to token systems (e.g., Flora & Pavlik, 1992; Hyten et al., 1994), with children (Schweitzer & Sulzer-Azaroff, 1988), and with individuals with mental retardation (Ragotzy, Blakely, & Poling, 1988) who received tangible reinforcers. The results also support the findings of applied studies (Neef et al., 1993; Vollmer et al., 1999).

Jackson and Hackenberg's (1996) study makes another point. Experiments 3 and 4 explored aspects of the procedure that may have controlled the pigeons' preferences for the large delayed reinforcer. Were the colored side keys and their relations to the differential food consequences controlling the birds' choices, rather than the LEDs? Results suggested that the intervening LEDs were important in maintaining selections of the key leading to large delayed reinforcement. For example, when responses to the choice keys led to their respective small and large reinforcers *without* the intervening LEDs, the pigeons selected the key related to large delayed reinforcement less often. The results are consistent with the positive effects of presenting cues or signals during the delays to reinforcement.

Application: Intervening stimuli. Jackson and Hackenberg (1996) were able to establish the pigeons' preferences for large reinforcers and maintain those preferences as the delay to token exchange was increased. Their study suggests a two-part program to establish self-control: (a) While maintaining preferences for the large reinforcer, gradually increase the delays equally for both small and large reinforcers, then (b) while holding the long delay constant, gradually decrease the delay before the small reinforcer. This approach resembles others used in the laboratory to establish self-control choice by gradually increasing the delay to the large reinforcer in children identified as impulsive (Schweitzer & Sulzer-Azaroff, 1988) and in individuals with mental retardation in both laboratory (Ragotzy et al., 1988) and applied (Dixon et al., 1998) settings. However, few studies of self-control with humans with limited development have used tokens (but see Burns & Osborne, 1975); instead, terminal reinforcers (e.g., stickers, snacks, time socializing) were delivered either immediately or after a delay. An obvious advantage of the systematic use of tokens with such individuals includes the possibility that longer delays in reinforcement may be possible without degrading self-control, in part because of the variety of reinforcers that can be delivered during the token-exchange period.

If tokens are used to encourage schedule following and mediate the delivery of delayed reinforcers, behavior analysts will find a wealth of programmatic ideas already available in the applied literature (e.g., Kazdin, 1982; Kazdin & Bootzin, 1972), backed up by an informative collection of laboratory articles on relevant topics like conditioned reinforcement (e.g., B. A. Williams, 1994). The basic studies can inform the applied researcher, just as the basic research focused on in this paper reminds us that whether tokens function as conditioned reinforcers will depend on a relevant learning history (B. A. Williams, 1999), and that the successful use of tokens demands an appreciation for the scheduling of token delivery, token exchange, and delivery of terminal reinforcers (Jackson & Hackenberg, 1996). Consideration must also be given to the long-term effectiveness of tokens in maintaining desirable behaviors.

Although the analysis of procedures for increasing self-control in applied settings has begun (Dixon et al., 1998), the role of signally stimuli—marking, bridging, or reinforcing in nature—has not been explored systematically. Jackson and Hackenberg's (1996) data suggest that the scheduling of intervening stimuli might increase preferences for delayed terminal reinforcers. As a step in this direction, Vollmer et al. (1999) showed that participants with developmental disabilities and severe challenging behaviors were more likely to exhibit self-control than impulsive choices when the longer delays were signaled rather than unsignaled. It would be worthwhile to determine whether the use of tokens or other methods of establishing behavioral chains could expand the kind of self-control repertoire examined in Vollmer et al.'s study. The outcome could be the development of methods that teach such individuals to engage in greater and greater amounts of behavior for delayed reinforcers.

Concluding Comments

We examined three laboratory studies concerned with delayed reinforcement and explored their relevance for applied research and practice. A. M. Williams and Lattal's (1999) study with pigeons suggests that unsignaled delayed reinforcement might exercise control over behavior in contexts in which relatively few sources of competing behavioral control exist. B. A. Williams' (1999) study with rats indicates that the effects of delayed reinforcement may be strengthened by presenting exteroceptive signals during the delay before reinforcement delivery, especially if the intervening stimuli function as conditioned reinforcers. Finally, Jackson and Hackenberg's (1996) study with pigeons demonstrates that the use of intervening stimuli might increase the likelihood with which large delayed reinforcers are chosen over small immediate reinforcers. Integrating the findings and adapting the methods of such basic research will have implications for applied analyses of delayed reinforcement, including studies described previously on social behavior (Baer et al., 1984; Fowler & Baer, 1981) and adaptive choice making (Dixon et al., 1998; Vollmer et al., 1999).

A number of applied research questions are suggested by basic research on delayed reinforcement. Under what conditions are signals necessary for the maintenance of appropriate alternative behavior? Under what conditions is it necessary to include a DRO component to avoid establishing a response chain that includes aberrant behavior? Under what conditions is delayed reinforcement effective in establishing a functionally equivalent appropriate alternative response to compete with aberrant behavior?

There may be small or large delays that accompany the scheduling of these events, and teachers are faced with the challenge of encouraging students to learn to behave appropriately nonetheless. Likewise, there may be terminal reinforcers that, as mentioned above, are available only probabilistically. Selection of procedures aimed at producing effective behavior change that can be maintained over time and generalizes across settings (Stokes & Baer, 1977; and see Baer et al., 1984; Fowler & Baer, 1981) should be informed by an understanding of the basic behavioral processes.

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